A Final Progress Report
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# PARTICIPATION IN THE U.S. DEPARTMENT OF ENERGY REACTOR SHARING PROGRAM

Submitted to:

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## SECTION I

## CONTRACTUAL INFORMATION

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| Title: | Participation in the U.S. Department of Energy Reactor Sharing Program |
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| Submitted by: | Dept. of Mechanical, Aerospace and Nuclear Engineering<br>School of Engineering and Applied Science<br>University of Virginia, Thornton Hall<br>Charlottesville, Virginia 22903 |
| Project Director: | R.U. Mulder<br>Director of Reactor Facility and Associate Professor |
| Duration: | October 1, 1996 through September 29, 1997 |
| Funds granted: | $8,000 |
| Type of Business: | Educational Institution |
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## SECTION II

## FINAL PROGRESS REPORT
## Oct. 1, 1996 - Sep. 29, 1997

### A. INTRODUCTION

The University of Virginia Reactor Facility is an integral part of the Department of Mechanical, Aerospace and Nuclear Engineering. As such, it is effectively used to support educational programs in engineering and science at the University of Virginia as well as those at other area colleges and universities. The expansion of support to educational programs in the mid-east region is a major objective.

### B. SUMMARY OF OBJECTIVES AND UVA'S PARTICIPATION IN DOE'S REACTOR SHARING PROGRAM

The objective of the DOE supported Reactor Sharing Program is to increase the availability of university nuclear reactor facilities to non-reactor-owning educational institutions. The educational and research programs of these user institutions is enhanced by the use of the nuclear facilities.

Several methods have been used by the UVA Reactor Facility to achieve this objective. First, many college and secondary school groups toured the Reactor Facility and viewed the UVAR reactor and associated experimental facilities. Second, advanced undergraduate and graduate classes from area colleges and universities visited the facility to perform experiments in nuclear engineering and physics which would not be possible at the user institution. Third, irradiation and analysis services at the Facility have been made available for research by faculty and students from user institutions. Fourth, some institutions have received activated material from UVA for use at their institutions. These areas are discussed below.

## B.1. TOURS BY COLLEGES AND PRIMARY/SECONDARY SCHOOLS

By far the most popular activity offered under the Reactor Sharing Program at UVA are tours of the reactor facility and associated laboratories. Many groups, either because of a lack of available time or a lack of the necessary background, do not desire to perform experiments but are most interested in a one to two hour tour. Much useful information can be conveyed during this time period and for many students this may be their only exposure to the research uses of nuclear fission.

## B.2. STUDENT PARTICIPATION IN EXPERIMENTS

A part of the Reactor Sharing Program involves groups of students visiting the Reactor Facility as part of a tour and performing experiments involving the reactor or the use of radioisotopes. Over 1000 students have participated in these activities. A summary of all the colleges and universities that have participated in tours and laboratories as part of the Reactor Sharing Program is provided in Table 2.

The most common experiments fall into three general areas. These are: Radiation and Radioactive Decay; Radioisotope Applications in Science and Industry; and Reactor Operations. A brief description of several of the available experiments is provided in Table 3. In addition, special experiments can be arranged to meet the needs of classes in biology, chemistry, physics, and other disciplines.

The use of neutron activation analysis for identification of the elemental composition of materials continues to be the most popular experiment. This is a result of the wide application of neutron activation analysis for research in many areas of science. In addition to learning how to use neutron activation analysis, the students also increase their understanding of radioactive decay and interaction of radiation with matter.

The second most requested experiment involves measurements of the decay of radioactive isotopes. The half-life of various short-lived reactor produced isotopes, such as aluminum-28 and magnesium-27, can be determined. Also, the decay of one isotope into another radioactive isotope is measured, to demonstrate the concept of decay chains.

The University of Virginia supplies background information to the course instructors who use the material to prepare the students for a visit to the Reactor Facility. Once at the Reactor Facility, the students perform experiments under the direction of a reactor staff member or a faculty member.

Most faculty members and students participating in these experiments have stated that they were an important addition to their classes. The positive impact of these experiments is also indicated by the number of classes making repeat visits. Table 1 gives a listing of participants in the program for 1996-1997 and Table 2 shows those institutions that have participated in the program throughout its history at the University of Virginia.

## B.3. ACADEMIC RESEARCH PROJECTS CONDUCTED AT UVA

Another objective of the Reactor Sharing Program is to offer the UVAR nuclear reactor and counting facilities for general use in research projects. For example, some experiments are being performed to determine the effects of radiation on materials. However, the major use is in the area of neutron activation analysis (NAA).

Neutron activation analysis is a method of determining the elemental composition of a sample by placing it in the neutron flux of a nuclear research reactor. The neutrons interact with elements in the sample, transforming a small fraction of these into radioactive isotopes. The quantity of isotopes produced is governed by the amount of each element present in the sample, the level of the neutron flux, and the irradiation time.

Once produced, each radioisotope emits characteristic gamma-rays, by which the elements in the sample can be identified. When the sample is "counted", using sensitive solid state radiation detectors, the amount of each radioactive element present can be determined precisely.

At the University of Virginia we are currently able to analyze samples for over 50 different elements. This analysis is expedited by the use of dedicated computers which calculate the elemental composition directly from the gamma-ray spectra, sample mass and irradiation conditions.

Over the last eighteen years, many professors and students from various universities have carried out research projects utilizing the Reactor Facility. In most cases, the experimenters are not familiar with activation analysis techniques and depend on the reactor staff for advice on sample preparation, NAA procedures, data reduction and analysis. In a number of instances samples are supplied to the staff by the experimenters in bulk form. Starting from this, the entire analysis procedure is done by one or more staff members. The results returned to the experimenters state the elemental concentrations found in the supplied samples. This year, an undergraduate student from New York University spent about half the summer at the Reactor Facility learning, and then using, neutron activation analysis techniques in his research. This was the only major research project completed this year and is listed in Table 1 along with the other work completed.

## B.4. IRRADIATION SERVICES OFFERED TO USER INSTITUTIONS

Commonly, researchers from outside institutions request that their materials be irradiated at UVA, either with neutrons or gamma-rays. These materials are then shipped to their institutions for analysis or use. Materials activated with neutrons are either analyzed on gamma-ray spectrographic equipment or the emitted radiation used in various experiments. The UVA cobalt-60 gamma-ray irradiation facilities can be used for sterilization, inducing mutation of biological materials, or to study the effect of high doses of radiation, which can result in changes in electronic component characteristics and the cross-linking of polymers. Gamma-ray irradiation of seeds, for investigation of radiation-induced genetic mutations, continues to be a popular high school science activity. Those using these services during the contract year are listed in Table 1.

## C. FINANCIAL REPORT

As noted in the most recent proposal, the charges for services provided under the Reactor Sharing Program were based on the number of hours of reactor operation required, at the established use charge of $100.00 per hour of exclusive use. Other facility charges include those for use of irradiation facilities and counting equipment.

Personnel charges for the research scientist responsible for conducting the program for the period from October 1996 through September 1997 of the totaled $6,242.40. Direct charges for reactor and laboratory use totaled $2,875.00. No charges were made against the program account for reports and mailings. The total charged against the Reactor Sharing account (both this year's new funds and funds carried over from previous years) for services rendered during the 1996-97 contract year was $9,117.40.

**TABLE 1**

**SUMMARY OF REACTOR SHARING PARTICIPATION**
**October 1, 1996 to September 29, 1997**

| | | | |
|---|---|---|---|
| University | : Univ. of Virginia | Location | : Charlottesville, Virginia |
| Program Director | : Dr. Robert Mulder | Telephone No. | : (804) 982-5440 |
| Grant Number | : DE-FG05-92ER75813 | Reactor Type | : 2 MW Pool Reactor (UVAR) |

| Date | Participating Institution | Instructor | Grade | Student/ Teachers | Program Description | Direct Cost |
|---|---|---|---|---|---|---|
| | COLLEGES | | | | | |
| 11/15/96 | Lynchburg College | N. Summerlin | UGS | 5 / 1 | Facility tour & laboratory | 50.00 |
| Summer 97 | New York University | M. McCann | UGS | 1 / 0 | Neutron activation analysis of many different phosphorescent minerals to investigate whether or not the levels of trace impurities can be related to the degree of phosphorescence or the color. | 2,625.00 |
| | | SUBTOTAL | | 6 / 1 | | 2,675.00 |
| | PRIMARY/SECONDARY SCHOOLS | | | | | |
| 10/17/96 | Charlottesville High School | E. Sturgill | PCS | 19 / 2 | Facility tour & laboratory | 50.00 |
| 10/25/96 | Charlottesville High School | E. Sturgill | PCS | 21 / 3 | Facility tour & laboratory | 50.00 |
| Nov. 96 | Oakton High School | K. Davis | PCS | 1 / 0 | Gamma-ray irradiation of seeds | 0.00 |
| 11/15/96 | Charlottesville High School | E. Sturgill | PCS | 9 / 3 | Facility tour & laboratory | 50.00 |
| 11/21/96 | King Geoge High School | H. Black | PCS | 27 / 5 | Facility tour | 0.00 |
| 12/11/96 | St. Anne's - Belfield | Elizabeth Kutchai | PCS | 15 / 1 | Facility tour | 0.00 |
| 12/19/96 | St. Anne's - Belfield | M.V. Liew | PCS | 29 / 3 | Facility tour (2 groups) | 0.00 |
| 01/13/97 | Jack Jouett Middle School | Carla Myrtle | PCS | 32 / 2 | Facility tour (2 groups) | 0.00 |
| 01/16/97 | St. Anne's - Belfield | Elizabeth Kutchai | PCS | 13 / 1 | Facility tour | 0.00 |
| Feb. 97 | Honaker High School | K. Stilwell | PCS | 0 / 1 | Gamma-ray irradiation of seeds | 0.00 |
| 03/01/97 | Boy Scout Troop | Bruce Sullivan | PCS | 15 / 13 | Facility tour | 0.00 |
| 03/18/97 | Little Keswick School | Aaron Parsons | PCS | 8 / 2 | Facility tour | 0.00 |
| 04/22/97 | Albemarle High School | Dave Ridenour | PCS | 32 / 2 | Facility tour & laboratory | 0.00 |
| 04/23/97 | Albemarle High School | Dave Ridenour | PCS | 38 / 2 | Facility tour & laboratory | 0.00 |
| 04/24/97 | Albemarle High School | Dave Ridenour | PCS | 28 / 4 | Facility tour & laboratory | 0.00 |
| 05/20/97 | Woodberry Forest School | Paul Vickers | PCS | 4 / 1 | Facility tour | 0.00 |
| 05/28/97 | Tandem Friends School | Lisa Beazell | PCS | 4 / 1 | Facility tour | 0.00 |
| 06/02/97 | Sharon Elementary School | Dave Peters | PCS | 21 / 4 | Facility tour | 0.00 |
| 06/26/97 | mixed elementary school | | PCS | 62 / 7 | Facility tour | 0.00 |
| Jun. 97 | Summer teachers class | Staff | PCS | 0 / 27 | Demonstration neutron activation analysis lab for group of high school and middle school teachers. | 50.00 |
| | | SUBTOTAL | | 378 / 84 | | 200.00 |
| | | TOTAL | | | | 2,875.00 |

| SUMMARY | Groups | Students | Teachers/Adults |
|---|---|---|---|
| Faculty | 0 | 0 | 0 |
| Graduate students (GS): | 0 | 0 | 0 |
| Undergraduate students (UGS): | 2 | 6 | 1 |
| Pre-college students (PCS): | 20 | 378 | 84 |
| Total: | 22 | 384 | 85 |

**TABLE 2**
**Summary of Participation in Laboratories, Projects and Tours Under the Auspices of the Reactor Sharing Program (September 1978 - September 1997)**

| University or College | This year | Discipline | Number of Interactions | Faculty Contact |
|---|---|---|---|---|
| Bridgewater College | | Chemistry | 1 | J. Martin |
| | | Physics | 2 | D. Neher |
| | | Physics | 1 | P. Spickler |
| | | Physics | 4 | J. Ulrich |
| Emory & Henry College | | Physics | 1 | C. Nelson |
| George Mason University | | Physics | 2 | Physics club |
| Hampton University | | Physics | 1 | K. Han |
| James Madison University | | Physics | 9 | J. Gordon |
| | | Physics | 1 | R. Serway |
| | | Nuclear Chemistry | 7 | D. Downey |
| | | Biology | 3 | M. Gordon |
| J.S. Reynolds Comm. College | | Chemistry | 1 | J. Martin |
| Longwood College | | Physics | 2 | L. Fawcett |
| | | Education | 1 | L. Banton |
| | | Archaeology | 1 | B. Bates |
| Lynchburg College | * | Chemistry | 20 | N. Summerlin |
| Mary Washington College | | Physics | 7 | R. Atalay |
| | | Physics | 1 | G. King |
| Piedmont Va. Comm. College | | Chemistry | 30 | R. Bratton |
| | | Physics | 1 | J. Wallpole |
| | | Physics | 4 | T. Lowe |
| Randolph Macon College | | Physics | 1 | W. Temple |
| Randolph Macon Women's College | | Physics | 2 | B. Mattson |
| Roanoke College | | Physics | 1 | W. Baldridge |
| | | Physics | 1 | J. Adams |
| Rutgers University | | Chem. Engr. | 1 | D. Berler |
| Rutgers University | | Civil & Environmental Engr. | 1 | I. Wojentko |
| Shepherd College | | Chemistry | 1 | W. Crum |
| S.W. Va. Community College | | Chemistry | 2 | R. Epling |
| Sweetbriar College | | Chemistry | 8 | H. Gager |
| University of Richmond | | Physics | 1 | W. Major |
| | | Physics | 1 | M. Vineyard |
| University of Houston | | Civil & Envir. Engr. | 1 | S. Garg |
| Virginia Commonwealth Univ. | | Physics | 2 | S. Herr |
| | | Chemistry | 2 | K. Goins |
| Virginia Military Institute | | Chemistry | 2 | R. Minnix |
| | | Chemistry | 5 | H. Schreiber |
| | | Physics | 2 | P. Peters |
| | | Psychology | 1 | D. Foster |
| Virginia Polytechnic Institute | | Physics | 14 | T. Parkinson |
| | | Env.&Haz.Mat. | 1 | D. Orvos |
| Washington & Lee | | Geology | 1 | S. Kozak |
| College of William & Mary | | Marine Science | 3 | J. Warinner |

Notes to Table 2:

* These institutions and faculty members participated in the Reactor Sharing Program during the current and/or previous contract year.

Additionally, numerous high school groups have toured the facility and some of these have also participated in laboratory exercises. In the 1996-97 contract year, 462 primary and secondary school students and their teachers visited the reactor as part of tour groups.

TABLE 3

EXPERIMENTS PERFORMED FOR THE UNIVERSITY OF VIRGINIA REACTOR SHARING PROGRAM

## A. RADIATION AND RADIOACTIVE DECAY OF ISOTOPES

1. Radiation Counting Statistics

Demonstration of the random nature of radioactive disintegrations at both low and high disintegration rates. Using a multi-scaler, series of counts are taken which, respectively, approach a Poisson distribution and a Gaussian distribution.

2. Radioisotope Decay and Half-Life Determination

Demonstration of radioactive decay and determination of reactor produced, short-lived isotope half-life, using a multi-scaler. More complex decay chains may also be demonstrated, such as decay of two isotopes with differing half-lives or decay of two isotopes, one of which is transformed by decay to the other.

3. Types of Radiation

Characterization of different types of radiation including determination of alpha- and beta-particle energy spectra, using silicon surface barrier devices, and gamma-ray spectra, using either a sodium-iodide scintillator or a germanium detector. Effectiveness of shielding materials for the various radiation types may also be demonstrated.

4. Radiation Intensity and Shielding

Demonstration of the decrease in radiation intensity as a function of the inverse square of distance from the radiation source. Determination of source activity from measured dose rates and radiation energy. Effectiveness of radiation shields may also be included.

## B. RADIOISOTOPE APPLICATIONS IN SCIENCE AND INDUSTRY

1. Neutron Activation Analysis

Demonstration of trace element analysis using neutron activation analysis. A sample is activated in the UVAR and its constituents determined from the nature of its radioactive decay. Activation analysis of a coin, lipstick, hair, environmental samples, or other samples may be performed.

2. X-Ray Fluorescence Analysis

Demonstration of the chemical analysis of thin samples using an Am-241 x-ray exciter source and a germanium-lithium low-energy photon spectrometer. The x-ray spectrum measured from the material is used to determine the chemical composition of the surface.

TABLE 3 (continued)

3. Industrial Applications of Radioisotopes

Demonstration of the use of radioisotopes in industrial applications, such as thickness gauging, liquid level sensing and flow detection. Beta, gamma and neutron sources are used.

## C. REACTOR EXPERIMENTS

1. Approach to Critical

Demonstration of the subcritical multiplication of neutrons until a self-sustaining fission reaction is obtained.

2. Reactor Dynamics and Safety Systems

Demonstration of changes in reactor power resulting from control rod position changes. Calibration of control rods and demonstration of reactor safety systems.

3. Decay Heat Following Reactor Shutdown

Measurement of heat generation from fission and fission product decay following a reactor shutdown. Measurements are read from nuclear instrumentation and calculated from primary system heat balance.